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AUTHOR Dale, Evelyn J.
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ABSTRACT

A 10-week project conducted with 12 gifted 4th and 5th grade students (10 boys and 2 girls) examined the effectiveness of the Logo computer programming language as a tool for helping students understand some basic principles of physics. Three assumptions were tested: (1) motivated elementary school students can learn both turtle graphics and word and list manipulation; (2) Logo provides a motivating environment for learning the ideas and concepts of physics; and (3) Logo makes the basic principles of physics understandable. Following 5 weeks of preparatory instruction in Logo, 5 weeks were used to explore simple physics problems with Logo vectors. (The Logo graphics allow dynamic illustrations of the computer's numerical solutions as they are being calculated.) Topics covered were free fall, projectile motion, and the cathode ray. In order to explore those subjects, students needed to understand the mathematical concepts of transposing values in an equation, the law of complementary angles, the Pythagorean theorem, and the trigonometric functions of sine, cosine, and tangent. Results indicate that students mastered the Logo commands and concepts required for the physics projects, found word and list manipulation surprisingly easy, and found learning physics with Logo extremely interesting. While this project was successful, it would need modification to be used with average ability students at this level. (LMM)

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A Logo-Physics Project

Evelyn J. Dale
820 Christie Court
Davis, California 95616

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Logo has become a powerful force in the field of computers-in-education. However, most of the research surrounding Logo's use has focused on questions associated with the programming process. Little work has been done with using the language as a tool for learning other subjects.

In January 1984, Professor James Hurley and I received a grant from the California State Department of Education to teach a Logo/Physics course at the Frontier School in Rio Linda California. The purpose of this project was to see whether Logo could be used to help students understand physics. The project was divided into two parts. The first part, which I taught, was devoted to learning Logo. It was my job to provide the students with enough knowledge of Logo to enable them to use it to do some interesting problems in physics. The second half of the program was taught by Professor Hurley, a member of the Physics Department at the University of California, Davis, and focused on using Logo to learn physics.

Why Computers?

Many interesting problems in physics are inaccessible to even high school students because they lack the mathematical knowledge to solve the problem. A numerical approach, however, provides a straight forward and much simpler way of solving such problems. This method has an added advantage of being versatile since it can be used to solve a wide range of problems such as projectile motion, planetary orbits, and radioactive decay. Unfortunately this process is tedious to do and produces a mass of data that is difficult to interprete. Computers, however, can

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solve these difficulties because numerical solutions can be substituted for mathematical ones and the results graphically mapped out on the screen. This approach enables students, whose mathematical background is less advanced, to explore interesting problems in physics.

Why Logo?

Logo was chosen for this project for several reasons. First, Logo's turtle graphics provides dynamic illustrations of the computer's numerical solutions as they are being calculated. This makes understanding the solution that much easier. For example, the turtle can draw the trajectory of an object as it moves through space at a particular velocity with a certain gravitational force acting upon it. As this is being done each part of the numerical solution can appear on the screen. Figure 1 demonstrates how velocity (horizontal line) and gravity (vertical line) might be drawn by the turtle to show the trajectory of a given object. This diagram however, looses some of its impact because it is static. Logo's capacity to combine graphics and motion to provide a dynamic illustration is both informative and fascinating. The ability to vary the numerical input to a program also gives students a chance to observe various solutions to the same problem.

Logo's turtle graphics is not only fascinating to watch, it is easy to learn and apply. This is because it is based on the familiar forward, back, right and left movement of the body. The important point here is that any object's movement through space can be described the same way. Thus the fundamental movement of

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a child's body can be used to describe the trajectory of a ball or the orbit of a planet as it revolves about the sun.

Logo's procedural structure is also familiar. This is because it reflects the procedural structure of language. Using Logo to communicate with the computer is similar to the way we communicate with our fellow human beings. That is to say, words and procedures, once defined, become multi-purpose and can be used in different contexts. For example, the word "ran" has a particular configuration. It can, however, be used in different contexts to produce different verbal images. For instance, "He ran after the ball," "She ran a computer program," "Geraldine Farroro ran for Vice President," or "My nose ran because I had a cold." Similarly, a Logo procedure called BOX can be used to create many different images. The end result depends upon how it is used in the program. Thus, while the word or procedure remains the same, what is actually communicated varies according to the context. This kind of modularity gives Logo the flexibility to handle many different problems.

Atari Logo was used in this project because its four turtles made projects such as planetary orbits or radio-active decay easy to execute. Commordore 64 and Sprite Logos also have multiple turtles but not all Logos do. With only one turtle the possibilities for physics projects are more limited.

Student Background

The project itself involved a group of ten boys and two girls from the Frontier School in the Rio Linda school district of California. These were gifted students who had CTBS scores

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averaging at the tenth grade level in mathematics. Each fifth and sixth grade teacher at the school referred four students to Nancy Weber, the project's coordinator. Nancy's job was to verify the students qualifications and help the teachers make up the final list of students. Sixteen children were chosen--twelve participants and four alternates with an equal number from each grade level. The selected students were then asked if they would like to participate and parent permission was requested.

Although every participant had had some computer experience, the amount of time and kinds of applications varied from playing an occassional game to writing programs. Five students had a computer at home. Eleven children listed Math as their favorite subject with the twelth listing English. Ten felt good about computers while two were made nervous by them. Three had worked with some version of Logo. It is interesting to note that although the one student who had Atari Logo at home and programmed with it did well, he was not the most successful student in the group.

Schedule, Setup and Hardware

The Logo/Physics project was ten weeks long with students meeting in the Atari lab for two hours every Friday afternoon. The first five weeks were taken up with learning Logo and were taught by me. The second five weeks concentrated on Logo's application to physics and were taught by Professor Hurley.

Twice a week students had an opportunity to go to the lab and work on their projects for one and a quarter hours after school. Although these sessions were optional, they were

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regularly attended by all the students. A teacher's aide was available to answer questions during these supplementary sessions.

The computer lab contained six Atari 800 computers with disk drives and printers. Students kept a Logo journal that contained their work, teacher hand outs (e.g., reference sheets, or explanations of projects), and any hard copies of their programs.

Purpose of Project

The purpose of this project was to test the following assumptions. First, motivated elementary school students can learn not only turtle graphics but word and list manipulation. Second, Logo provides a motivating environment for learning the ideas and concepts of physics. And finally, that Logo makes the basic principles of physics understandable.

The purpose of the first half of this ten week program was to prepare students for explorations of physics with Logo. In order to do this they needed to be able to read and understand fairly advanced Logo programs. In short, they needed to be Logo literate. This means that in ten hours of class time and a varying amount of extra lab time, students needed to understand not only turtle graphics, but Logo's Cartesian coordinate commands, arithmetic operations, proceduralization, recursion, conditional statements, variables, output, word and list manipulation.

The second five weeks involved the exploration of simple physics problems with Logo. The topics covered during this time

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were vectors, free fall, projectile motion and the cathode ray tube. In order to explore these subjects, students needed to also understand the following mathematical concepts: transposing values in an equation, the law of complementary angles, the Pythagorean Theorem and the Trigonometric functions of sine, cosine and tangent.

Throughout this project students either wrote their own programs or modified existing ones. This way they learned by applying the new concepts and ideas of physics in Logo programs.

Conclusions

It is important to remember that the twelve students involved in this project were above average in abilities and that the learning environment was unique in both its student-to-hardware and student-to-teacher ratios. Nevertheless, the results do tell something about the possibilities of learning more advanced Logo programming and the use of Logo to teach physics.

It may be helpful to discuss the results in the light of each of the three assumptions mentioned above. First, did these fifth and sixth graders go beyond turtle graphics? The answer is an emphatic yes. Every student mastered the Logo commands and concepts required to understand and do the physics projects. They were Logo literate after five weeks and understood how to read and write programs using three or more procedures, variables, recursion, conditional statements, etc.

Word and list manipulation was surprisingly easy. One reason for the ease with which they learned these more abstract

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operations is that they were used in the context of interesting and meaningful programs. Furthermore, students did not find it difficult to understand how Logo uses objects in a list. This may have been because the objects that were being manipulated were numbers whose symbolic nature turned out to be advantageous. That is to say, the students did not have to consider anything other than the process of pulling a number out of a list and using it to complete an arithmetic operation or place the turtle somewhere on the screen. When words are manipulated, their meaning gets in the way. It is not enough to pick a word and use it. The selected word's grammatical usage and its meaning must fit with the word or list with which it is being joined. For instance, if the word "RUN" is added to a list and printed out, it must appear in the proper place and be used in a grammatically correct way. "THE DOGS RUN," is fine but "THE RUN DOGS," and "RUN THE DOGS" are not. Manipulating numbers lets students focus on the process itself without worrying about the more complicated issues of meaning and grammatical usage.

Students found learning physics with Logo to be extremely interesting. Their evaluations at the end of the ten week project indicated they were anxious to continue their explorations and felt positive about the total experience. The program was rated "A" by eleven of the students and "B" by one.

Did Logo help to make the basic principles of physics clear? Students found that programming the turtle to behave according to certain laws of physics was extremely interesting. They especially enjoyed using their knowledge of trajectories to

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hit a target. As a result of their work, students had a more concrete understanding of terms such as velocity, angle and gravity and how they affect an object's motion.

There were two problems that became clear as the project progressed. The first was simply the issue of time. This is not an unusual problem for such projects. There is always so much more that could be accomplished if the program could continue a bit longer. With this project students were beginning to really get into the subject of physics when the ten weeks were finished. They had learned a great deal of Logo but had just begun to get into the subject of physics. Nevertheless, the students accomplished a great deal in the time available.

A more serious obstacle to the understanding of physics was the students' mathematical background. Although they were all above grade level in mathematics they had to be introduced to concepts such as transposition and the trigonomentric functions of sine, cosine and tangent before they could work with projects such as projectile motion. Teaching these mathematical concepts took time away from the actual explorations of physics.

While this project was successful, it seems appropriate to point out that while numerical solutions can be used to do a major portion of Logo/physics programs, there are still certain mathematical concepts that students need to know. Since the students in this program were gifted and highly motivated, they were able, for the most part, to learn the necessary mathematics. To use the program in the average fifth or sixth grade classroom would require modification. Explorations for

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these students should be slower and, at first, limited to simply running the programs and observing how the turtle's actions reflect the laws of physics. Changing the actual programs would take place only after students were acquainted with the required mathematics.

For most students, such a Logo/Physics course would be more appropriate when they ordinarily take physics in high school. Students would then have the necessary background in algebra and trigonometry to follow the programs with ease. The difference Logo would make to the traditional high school physics curriculum would be that, with Logo to do the numerical calculations and graphically represent them on the screen, students could work with more advanced problems.

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FIGURE 1

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